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OPTIMIZING THE OPPORTUNITIES FOR SPECIALITY OAT VARIETIES IN FEEDLOT RATIONS

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Optimizing the Opportunities for Specialty Oat Varieties in Feedlot Rations

Final Report

To

The Saskatchewan Agriculture Development Fund

Project # 20050727

By

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Executive Summary:

Recently The Crop Development Center at the University of Saskatchewan developed a new variety of oat CDC SO-I, with low lignin hull and high oil groat. This new variety of oat is specially developed for the ruminant feed market. Previous feeding trials with initial lines of this variety have shown promise in both dairy and feeding trials, particularly in backgrounding programs where inclusion levels have been relatively low. However, in finishing trials (Zalinko and McKinnon unpublished) it was noted that this variety resulted in a depression in feed intake when fed at high inclusion levels, potentially due to an effect of processing (hull separation) and/or high oil content of the diet. The objective of the research described in this report was to determine feeding recommendations for CDC SO-I oat that can be used by the oat and cattle industries to maximize the use of this cereal grain which is attractive from both an agronomic and nutritional perspective. Specifically to determine what fat level of the diet achieved by feeding high fat oat can be targeted to optimize performance and carcass quality relative to barley fed cattle.

Three trials were conducted to evaluate the effects of dietary inclusion level of a low lignin hull, high oil oat (CDC SO-I) on the performance and carcass characteristics of feedlot cattle. In trial 1, 200 crossbred steers (average weight of 400 kg) were used in a 162 day trial. Five treatments were formulated by replacing barley with increasing level of CDC SO-I oat. These included barley grain: CDC SO-I oat ratios of 100:0; 75:25; 50:50; 25:75 and 0:100 (as fed basis). Performance variables studied were DMI, ADG, feed efficiency, ultrasound subcutaneous fat depth (SC) (mm) and longissimus dorsi area (cm^2). Over the entire study there was a linear decrease ($P < 0.05$) in DMI and ADG with increasing inclusion levels of CDC SO-I oat, whereas feed efficiency (gain:feed) decreased ($P < 0.05$) quadratically. Number of days on feed also increased ($P < 0.05$) quadratically for the steers fed higher inclusion levels of CDC SO-I oat. Increasing the inclusion level of CDC SO-I oat in the diet also decreased ($P < 0.05$) carcass weight, dressing % and grade fat linearly. However, there was no effect of treatment on grader REA and lean yield %. There was no significant effect of treatment on marbling score. While the results of this trial point to a negative effect of CDC SO-I on performance,

there were minimal differences between performance of cattle fed all barley versus those fed a 75% barley: 25% oat blend.

Trial 2 involved a metabolism trial to determine the effect of CDC SO-I inclusion level on rumen fermentation parameters of 5 fistulated heifers fed a finishing diet. No negative effect of oat inclusion level was noted on any aspect of rumen fermentation.

Trial 3 was a backgrounding trial run at the Western Beef Development Centre to examine the need for processing the CDC SO-I oat prior to feeding. Comparisons were made between rolled barley and rolled or whole CDC SO-I oat fed in hay based backgrounding diets. The results of this trial indicate that the new variety of oat – CDC SO-I is an excellent feed oat for backgrounding cattle and does not require processing prior to feeding. Performance of calves fed either whole or rolled CDC SO-I oat was at least equal to that of barley-fed calves and in fact feed to gain ratio tended (P=0.13) to be superior for calves fed the whole oat diet.

Over all, the results of this study indicate that replacement of barley by CDC SO-I oat in finishing diets decreases dry matter intake and as a result leads to reduced ADG, increased days on feed and lower slaughter and carcass weights. The results would point to a maximum level of 25% CDC SO-I oat in the diets of finishing cattle. No negative effects of CDC SO-I oat relative to barley were noted on rumen fermentation parameters. However, as with barley-based diets there is a need for proper feeding and bunk management protocols to minimize digestive disturbances such as sub-acute acidosis. Results of the backgrounding trial show that this product is an excellent feed grain for growing cattle and that processing (i.e. dry rolling) is not necessary when CDC SO-I oat is fed at approximately 35% (DM basis) in diets designed to target approximately 1.2 kg gain in backgrounding programs. As such, in addition to the agronomic benefits of growing oat for feed, producers will save the processing costs typically required for barley feeding programs yet achieve equal performance. These savings typically range fro $5 to $15 per tone depending on operation size and method of processing employed.

Introduction:

Recently the Crop Development Center of the University of Saskatchewan developed a new variety of oat CDC SO-I, with a low lignin hull and high oil groat. This new variety of oat is specially developed for the ruminant feed market.

The nutritional value of oat can be increased by increasing its digestible energy content. By increasing the oil and reducing the lignin content (indigestible part) of grain, the digestibility and caloric value can be improved. This is the intent of the oat breeding project at the Crop Development Centre (CDC). The CDC developed and recently released this new variety of oat (CDC SO-I). It has two unique characteristics. In any normal oat variety, the hull which is high in lignin constitutes 20 to 25 per cent of the oat. The hull content of this new variety is still the same as other oat varieties, but as a result of low lignin content (1.5% DM) it is more digestible and thus more useable as an energy source. Another characteristic of this variety is its high-oil groat (8.5-9.0% DM), which also contributes to its increased energy value.

These unique nutritional characteristics and the favorable agronomic properties of oat relative to barley in many areas of Saskatchewan, make this variety attractive to both cattle feeders and grain producers. However, previous research (Zalinko and McKinnon, unpublished) on this variety with cattle has shown variable results. In backgrounding diets, animals fed this variety had similar intake and equal performance in terms of feed conversion efficiency and average daily gain compared to barely fed cattle, however during finishing, animals fed diets containing 75% or more of this oat line had lower dry matter intakes and daily gains which resulted in reduced carcass weights, lower dressing %, reduced grade fat and reduced rib eye area. One of the concerns stemming from this work is the effects of the added fat from this line of oat on rumen fermentation characteristics and thus intake of the cattle. Excess added fat can reduce intake and thus lead to reduced performance. This leads us to ask the following questions:

- what is the optimal level of CDC SO-I oat for finishing cattle?
- what are the rumen degradability and fermentation characteristics of this oat variety?
- is there a need to process this oat variety for backgrounding cattle?

The hypothesis of our research is: ***that strategic supplementation of high fat-low lignin oat in the growing and finishing rations can result in performance superior to or equal to that of barley-fed cattle***.

The following work was initiated to test this hypothesis and provide data so that CDC SO-I can be used in the development of the feed oat market.

Study 1: Effect of Dietary Inclusion Levels of Low Lignin Hull, High Oil Oat on the Performance and Carcass Characteristics of Feedlot Cattle

Introduction

Oat grain (Avena sativa) is not typically included as an energy source in the diets of growing and finishing cattle. This is due to its high hull content which typically averages 25% of the oat kernel and the indigestible nature of the hull, being comprised of 5.5 to 6.0 % acid detergent lignin (Thompson et al. 2002). These characteristics result in lower net energy values for oat (International Reference # 4-03-309: 1.85 and 1.22 Mcal kg DM NE_m & NE_g, respectively) compared to barley (International Reference # 4-00-549: 2.06 and 1.40 Mcal kg DM NE_m & NE_g, respectively) and corn (International Reference # 4-02-931: 2.18 and 1.50 Mcal kg DM NE_m & NE_g, respectively) (NRC, 1996). This despite the fact that oat grain (5.2%) typically has a higher fat content that either barley (2.2%) or corn grain (4.3%) (NRC, 1996).

The nutritional value of oat grain can be increased through plant breeding by increasing the oil content of the groat and/or reducing the lignin content (indigestible part) of the hull (Devlin et al. 1977). It has been reported that an oat-based diet with a low-lignin hull cultivar resulted in improved organic matter digestibility, increased apparent digestibilities of NDF, ADF and improved ruminal degradability of fiber components in comparison to an oat cultivar with a high-lignin hull (Rowe and Crosbie 1988) Thompson et al. (2000) reported increased in situ DM digestibility for low lignin hulls from Assiniboia oat relative to 8 other varieties of oat.

The Crop Development Centre (CDC) of the University of Saskatchewan recently developed a new variety of oat licensed as CDC SO-I with two unique characteristics: a low lignin hull (1.5% DM) and a high oil groat (6% DM). CDC SO-I oat is specially

developed for the ruminant feed market. A recent study by Niu et al. (2007) compared the *in situ* degradation characteristics of CDC SO-I oat and conventional oat cultivars and reported that CDC SO-I oat is more digestible due to its lower lignin and non fiber carbohydrates. However, unpublished results from our laboratory (Zalinko and McKinnon) with steers fed a prototype of this variety with a similar lignin content to the hull (i.e. 1.5% DM) but a slightly higher oil content to the groat (8.5-9.0% DM) indicated a negative effect on dry matter intake and performance of finishing cattle when barley or corn was replaced by this new oat variety. It was hypothesized that the reduced feed intake during this earlier study was due to the relative high level of dietary fat in the oat diet relative to either the barley or corn diets. Further research is required to determine the optimal level of this new oat variety in finishing diets and to determine if it can replace barley grain as the energy source in finishing diets.

The objective of this study was to investigate the effect of increasing inclusion level of CDC SO-I oat in finishing diets on DMI, performance and carcass characteristics of feedlot cattle.

MATERIALS AND METHODS

Animal and Diet

Two hundred crossbred steers (average weight 400 kgs) were purchased from a local auction market by the Dept. of Animal and Poultry Science and used for 162 day finishing study at the Beef Cattle Research Station, University of Saskatchewan, Saskatoon, SK. All steers were identified and processed on arrival including vaccination against clostridial disease, infectious bovine rhinotracheitis, bovine respiratory syncytial virus, bovine viral diarrhea, Haemophilus somnus, Pasteurella haemolytica and parainfluenza 3, and treated for parasites with Ivomec™ (MSD AgVet, Division of Merck Frosst Canada Inc., Kirkland, QC). At arrival all steers were implanted with Synovex S™ (xx) and re-implanted after 90 days with Synovex Choice™ (xx). Steers were stratified by weight and assigned to one of twenty outdoor pens (10 head per pen). Each of the 20 pens was randomly assigned to one of five treatments. All animals were cared for as per the guidelines laid down by Canadian Council on Animal Care (1993).

The CDC-SO-I oat and barley were grown on the University of Saskatchewan farm, Saskatoon, Sk., in 2006. Prior to the start of the trial the oat grain was cleaned (5.5 slotted sieve) to remove any thin unfilled kernels (Table 1).

Prior to the start of the trial, the steers were fed a silage-based backgrounding diet (50% silage, 30% barley, 5% supplement and 15% grass hay, DM basis). The cattle were adapted to the treatment diets over a 2 week period by gradually decreasing the forage and increasing the grain until the final desired forage to grain level was reached (Table 2). The control diet was composed of barley grain (88.4%), barley silage (6.2%) and a pelleted supplement 5.5% (DM basis). In diets 2 through 5, oat replaced 25, 50, 75 and 100% of the barley grain portion of the diet (DM basis), respectively. Both grains were dry rolled to ensure hull breakage and endosperm exposure using a Roskamp Series 9 Model J double roll roller mill with fine and coarse groove rolls. The ingredient composition of the pelleted supplement is given in Table 2. Steers were fed *ad libitum* twice daily at 0900 and 1600 h. Daily pen feed intake values were recorded. Samples of forages and concentrates were taken weekly to determine DM content while the bunk samples of total mixed rations and orts were taken every 2 weeks.

Performance Measurements

All cattle were weighed on two consecutive days prior to the morning feeding at the start and end of test to determine initial and final weights as well as every 14 days throughout the trial. Ultrasound measurements of subcutaneous fat (SC) depth and longissimus dorsi (*l.dorsi*) area were taken at the start and end of test and once every month according to the procedures of Bergen et al. (1997) using an Aloka 500 V realtime ultrasound machine and a 17 cm linear array transducer (Aloka 500, Corometrics Medical System, Wallingford, CT). The target end point was set at 650 kg (shrunk weight basis). All cattle were slaughtered having reached this end point at a commercial packing plant (XL Beef Inc., Moose Jaw, SK). Carcass traits including dressing %, grade fat, marbling score and lean yield were collected by federal graders.

Chemical Analysis

Forages were oven dried at 55°C for 48 h and together with all other feed samples were ground to pass through a 1-mm screen (Christy & Norris Laboratory Mill, Christy & Norris Ltd, Chelmsford, England). Feed samples were analyzed for DM by drying at 135°C for 2 h (method 930.15); ADF using an Ankom 200 fibre analyzer (method 973.18); CP using a 2400 Kjeltec analyzer unit (method 984.13), ether extract (EE) (method 920.39) and acid detergent lignin (ADL) (method 973.18 followed by 72% H_2SO_4 treatment) (AOAC, 1990). Neutral detergent fibre (NDF) content was determined with heat stable α-amylase and sodium sulfite (Van Soest et al., 1991). Calcium (method 927.02) and P (using molybdovanadate reagent; method 965.17) were analyzed after ashing for 5 h at 500°C using atomic absorption and UV visible spectrophotometer, respectively (AOAC, 1990). All measurements were performed in duplicate.

Particle Size Separation

Samples of grain, orts and total mixed ration were subjected to particle size separation using a three step procedure. Initially, a Carter-Day dockage tester (Carter-Day Co., Minneapolis, MN, USA) with round-hole sieves (screen size-0.30 and 0.25 cm) and riddle with 26 holes across (#25 riddle) was used to separate hulls, large particles and fines. Large particles were further air classified using a seed blower (Ames Powercount Co., Brookings, SD, USA) to separate hull particles. In the last step, particles left below the column were further sorted as per their density using a Spherical- Nonspherical sorter (Agriculex SNS-1, Canada) with lateral slope adjustment of 14 cm and horizontal slope adjustment of 5.5 cm at the Crop Field Science Laboratory, University of Saskatchewan. The same steps were repeated until the entire sample was separated and then collected in separate pre-weighed paper bags. Separated samples were weighed, dried thoroughly at 55°C and weighed to determine DM content. The proportion of hulls, large particles and fines was reported as a percent of the entire feed sample (DM basis).

Statistical Analysis

The trial was conducted as a completely randomized design with pen as the experimental unit. The Proc Mixed Procedure of the Statistical Analysis System (SAS Institute, Inc.

Cary, NC, 2003) with treatment as a fixed effect was used to carry out the analysis of variance for all performance and carcass results. Significance was declared at $P \leq 0.05$. Polynomial orthogonal contrasts were used to test for linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion level. The Kenward Roger adjustment on denominator degrees of freedom was used. For the marbling data, the glimmix macro provided by SAS Institute, Inc. (SAS Institute, Inc. Cary, NC) was utilized with a binomial error structure and logit transformation of data.

RESULTS AND DISCUSSION

The composition and chemical analysis of the total mixed rations are given in Table 1. All treatment diets met or exceeded NRC (1996) requirements for the type of cattle and rate of gain expected in this trial. As such there was no need for any supplemental protein in any diet. Replacement of barley with CDC SO-I oat resulted in increased levels of ADF, NDF and EE, while ADL levels decreased with higher inclusion rates of CDC SO-I oat (Table 2). These differences reflect nutrient profiles of the barley and oat grain used in the trial (Table 1).

Performance Data

Our hypothesis was that strategic supplementation of the high fat, low lignin oat in the finishing ration would result in performance equal to or superior to that of barley-fed cattle. The effects of different inclusion levels of barley and CDC SO-I oat on the performance of feedlot steers is given in Table 3. From day 1 to 86 of the trial, steers fed increasing levels of CDC SO-I oat exhibited a linear decrease in ADG ($P< 0.05$), DMI ($P< 0.05$) and feed efficiency (gain:feed ratio) ($P< 0.05$). Average daily gain and DMI and gain:feed for the barley-fed cattle were 112, 108 and 104% of the 100% oat-fed cattle. From day 86 to slaughter, both DMI and ADG continued to exhibit a linear decrease ($P< 0.05$) as CDC SO-I oat inclusion levels increased. However, gain:feed during this period exhibited a cubic effect ($P< 0.05$) with poorest efficiencies at 25% and 100% CDC SO-I oat (Table 3). As a result over the course of the entire trial DMI ($P< 0.05$) and ADG ($P< 0.05$) decreased linearly as CDC SO-I inclusion level increased, while feed efficiency showed a quadratic ($P< 0.05$) response with the poorest efficiency

at 100% CDC SO-I oat inclusion level. Days on feed increased ($P< 0.05$) in a quadratic fashion as CDC SO-I oat inclusion level increased. It should be noted that while performance was found to decrease linearly, the effects of the new variety were greatest at the 50% inclusion level or greater. For example over the course of the trial, DMI, ADG gain:feed and days on feed were very similar between the control and the 25% CDC SO-I inclusion level (Table 3).

Performance and feed intake of cattle fed the 100% barley-based control diet was similar to or superior to that reported by other workers who fed barley-based finishing rations to steers in a similar environment (Block et al. 2001; Williams et al. 2008). Superior performance of barley vs. oat fed cattle has been reported by other workers (Staigmiller and Adams 1989). However, due to the nature of CDC SO-I (i.e. low lignin hull; high oil groat), the results of the present study were not expected. Typically one would expect that productive efficiency of cattle would be improved by adding a more digestible, higher energy feedstuff to the ration. Fat addition to finishing diets is a common method to improve the productive efficiency of cattle by increasing the energy density of the diet (Allen, 2000; Hess et al. 2008). Several early studies have shown that addition of 4 to 8% tallow or blended tallow-vegetable oil mixtures to finishing diets will improve daily gain, and/or feed efficiency (Zinn, 1989a; Ramirez and Zinn, 2000; Huffman et al. 1992). However, it is clear that the increased lipid content of the CDC SO-I oat did not compensate for reduced dry matter intake in this study.

Research with fat addition to cattle diets has in some cases shown a negative effect of fat supplementation on dry matter intake, particularly when dietary fat levels approach 8% or greater. Reasons attributed to this negative influence include effects on rumen fermentation and/or gut motility, palatability of the diet or systemic effects on endocrine and hepatic metabolism (Allen 2000). For example, Zinn (1989b) found that supplementation of either 4 or 8% fat in the diet of feedlot cattle fed a barley-based finishing diet resulted in depressed ruminal and total tract digestion of organic matter, starch and ADF. Ramirez and Zinn (2000) reported both a depression in dry matter intake and in ruminal and total tract digestion of organic matter and neutral detergent fibre when 4% tallow, yellow grease or griddle grease was added to a diet with a magnesium level of

0.18%. Depressions in nutrient utilization however are not always a response to added fat (Huffman 1992; Atkinson et al. (2006).

In the current study, the total fat level of the 100% oat diet was 6.0% (DM basis). This level of fat addition is not typically associated a depression in feed intake, particularly of the magnitude seen in the current study (i.e. 10.9 vs. 9.7 kg / d for the 100% barley-fed vs. the 100% oat-fed cattle; Table3). Allen (2000) indicates that the hypophagic effects of added fat are not only associated with the level of fat addition but also with the proportion of unsaturated fatty acids. Harvatine and Allen (2005) noted a reduction in DMI of Holstein cows of 0.8 kg per day when fed 2.5% added fatty acids in the form of unsaturated vs. saturated fat. The unsaturated fatty acids were derived from calcium salts of palm fatty acid while the saturated fatty acids were derived from prilled hydrogenated free fatty acid. Gibb et al. (2004) noted a 14% reduction in dry matter intake of steers fed high linoleic acid sunflower seeds relative to those fed a control barley grain-based diet but no effect of feeding high oleic acid sunflower seeds. No effect of either treatment was evident with corn-based diets. Zalinko (unpublished) noted the following differences between a prototype of the CDC SO-I oat and barley in terms of fatty acid profile. The oat gain had a fatty acid profile (% of total extracted fatty acids) relative to barley grain of 14.6 vs. 19.9% for palmitic acid; 1.45 vs. 1.1% for stearic acid; 44.1 vs. 14.9% for oleic acid; 37.3 vs. 56.4 for linoleic acid and 1.1 vs. 6.6 % for arachidonic acid. The percentage of fatty acids with chain length greater than C18:0 was 84 and 78.8 % for the oat and barley grain, respectively. These values for CDC SO-I oat were similar to the fatty acid profile of oat grain that had been selected through 9 cycles for increased oil content (Holland et al. 2001). While barley has a higher proportion of C18:2n6 (i.e. 56.4 vs. 37.3 %), when one considers that the 100% oat-based diet had a total fat content of 6% vs. 2.6% for the 100% barley based diet, it is possible that the higher consumption of unsaturated fatty acids as oat level in the diet increased may have contributed to the reduction in dry matter intake seen in this study. This would be particularly true for diets with 50% and greater oat content. Long chain fatty acids released in the rumen are known to have toxic effects on gram negative bacteria (Angelidaki & Ahring 1992) which can lead to negative effects on digestibility and intake. It is of significance that oat contains a potent lipase that has been shown to work

at pH conditions encountered in the rumen. Decline in dry matter intake particularly at the higher oat inclusion levels would translate into reduced energy intake and as a result lower total body and carcass weights as well as longer days on feed to a fixed target end-point. All results observed in this study.

The negative effects of high dietary fat levels on the intake and subsequent performance of the 100% oat-fed steers is not the only possible explanation for the linear decrease in feed intake as oat level in the diet increased from 0 to 100% and dietary fat levels increased from 2.6 to 6.0% (Table 2). An alternative explanation for the decline in dry matter intake associated with increasing levels of the new oat variety may be associated with the nature of the oat kernel and the effects of processing. The oat kernel is comprised of the hull (~25%) and the groat. The groat is high in protein, starch and oil (Crosbie et al.1985). Table 4 indicates that processing, either dry rolling and/or mixing in the feed wagon results in a higher proportion of hulls in the oat and oat-based diets than in the barley or barley diets. Examination of the orts indicates that the refused feed of the 100% barley diet had 12.3% less hulls than that of the 100% oat-based diet (Table 4). Separation of hull from the groat during processing and/or diet mixing could result in a greater intake of the groat versus the hull for the oat-fed cattle. Consumption of a more concentrated form of energy in the form of the groat could lead to problems with acidosis or enhance the negative effect of the fat content of the groat and thus lead to reduced dry matter intake. This effect could explain the linear drop in dry matter intake as dietary inclusion level of the oat increased.

Carcass Traits

Steers fed higher inclusion levels of CDC SO-I oat had reduced ($P< 0.05$) carcass weight, lower ($P< 0.05$) dressing % and reduced ($P< 0.05$) grade fat. These results reflect the lower dry matter intake of the steers fed the oat-based diet. No treatment differences were noted for grader ribeye area (REA) and lean yield % (Table.5). Ultrasonographic measurements of backfat thickness and REA indicated that backfat thickness tended to be lower ($P = 0.07$) and REA decreased ($P < 0.05$) linearly for steers fed higher levels of CDC SO-I oat (Table.6). These results indicated slower rate of development of adipose tissue and muscle in CDC SO-I oat fed steers.

Percentage of steers fed diets consisting of different inclusion levels of CDC SO-I oat with different marbling scores are given in table 7. There was no effect of treatment on percentage of steers with AA and AAA marbling scores, while percentage of steers with marbling score A tended to be higher (P=0.07) with higher inclusion levels of CDC SO-I oat (Table.7).

CONCLUSIONS

Replacement of barley grain with CDC SO-I oat resulted in reduced performance and carcass characteristics of finishing steers. This was particularly true for cattle fed diets with 50% or more oat as the cereal grain. The reduced performance and carcass characteristics were a direct result of reduced DM intake and as a consequence reduced energy intake. This resulted in longer days on feed to a targeted finishing weight. The reduced dry matter intake was attributed to the relative high unsaturated fatty acids fatty acid content of the CDC SO-I oat. The negative effect of fat content on feed intake may have been enhanced by the relative ease which the hull was dislodged from the groat during processing and/or mixing. This separation could lead to sorting in the bunk and thus a greater intake of the groat relative to the whole kernel which would increase the lipid and starch density of ingested feed. This could further enhance the negative effects of high fat levels on feed intake.

Table 1. Ingredient and chemical composition of treatment diets used in feedlot finishing trial

	Barley grain : CDC SO-I oat				
	100% 0%	**75% 25%**	**50% 50%**	**25% 75%**	**0% 100%**
Ingredient Composition (% DM basis)					
Barley Silage	6.17	6.17	6.17	6.17	6.18
Pellets	5.48	5.49	5.49	5.49	5.49
Barley	88.35	66.28	44.20	22.10	0.00
Oats (LLHF)	0.00	22.07	44.15	66.23	88.33
Total	100.00	100.00	100.00	100.00	100.00
Pelleted Supplement (% DM basis)					
Barley	50.71	50.71	50.71	50.71	50.71
Canola Oil	3.46	3.46	3.46	3.46	3.46
Limestone	22.90	22.90	22.90	22.90	22.90
Rum Premix [1]	7.20	7.20	7.20	7.20	7.20
TM salt[2]	7.09	7.09	7.09	7.09	7.09
LS106[3]	8.64	8.64	8.64	8.64	8.64
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition (% DM basis)					
DM %	84.5	84.9	85.4	86.6	87.1
NDF%	20.2	21.9	23.3	24.5	27.4
ADF%	8.4	10.0	11.3	11.3	13.4
Ether Extract%	2.6	3.6	4.0	4.6	6.0
ADL %	3.1	2.8	2.6	2.3	1.9
Calcium %	0.48	0.45	0.46	0.46	0.51
Phosphorus %	0.38	0.36	0.33	0.36	0.35

1. Contained Barley 97%, Rumensin premix (Monensin Sodium 1000 mg/kg) 3%
2. Contained Zinc 10,000 mg/kg, Iodine 200mg/kg, Manganese 10,000 mg/kg, Copper 4000 mg/kg, Cobalt 60 mg/kg, Selenium 120 mg/kg, Salt 95%
3. Vitamin A 440500 IU/kg, Vitamin D 88,000 IU/kg

Table 2. Chemical composition of Oat and barley grain used in feedlot finishing trial

	CDC SO-I Oat Grain	Barley Grain
Nutrient	**Mean**	**Mean**
DM%	91.61	89.91
CP%	13.56	15.72
ADF%	12.62	6.24
NDF%	29.51	18.34
EE %	6.30	2.40
ADL%	1.70	1.90

Table 3. Effects of different inclusion levels of barley and oat (CDC SO-I) on the performance of feedlot steers

	Barley grain : CDC SO-I Oat						Contrasts[y]		
Parameter	**100:0**	**75:25**	**50:50**	**25:75**	**0:100**	**SEM[x]**	**Linear**	**Quadratic**	**Cubic**	**Quartic**
Live weight (Kg)										
Start of test	427.3	427.5	427	427.3	427.8	0.48	0.62	0.49	0.51	0.62
Day 86	599.5	600	591.5	584.8	582.3	3.36	0.0003	0.74	0.23	0.77
End of test	656.8	650.3	649.3	650.5	639.5	3.87	0.013	0.65	0.17	0.73
Day 1 to 86										
DMI (kg/d)	10	9.9	9.7	9.5	9.3	0.13	0.001	0.79	0.88	0.81
ADG (kg/d)	2.03	2.03	1.93	1.86	1.82	0.042	0.0005	0.69	0.31	0.68
Gain : feed	0.202	0.206	0.198	0.196	0.195	0.0033	0.033	0.71	0.23	0.48
Day 86 to Slaughter										
DMI(kg/d)	12.3	12.7	11.4	10.8	10.1	0.36	<0.0001	0.26	0.18	0.28
ADG(kg/d)	1.7	1.49	1.58	1.56	1.15	0.127	0.021	0.29	0.1	0.91
Gain : feed	0.138	0.117	0.138	0.144	0.113	0.008	0.38	0.25	0.01	0.58
Start of test to Slaughter										
DMI(kg/d)	10.9	10.9	10.5	10.1	9.7	0.17	<0.0001	0.35	0.53	0.84
ADG(kg/d)	1.93	1.91	1.85	1.77	1.59	0.045	<0.0001	0.06	0.58	0.77
Gain : feed	0.1759	0.1752	0.1763	0.1758	0.1633	0.0028	0.015	0.033	0.14	0.76
Days on feed	121	118	123	129	137	2.7	0.0002	0.031	0.46	0.68

[x] Pooled standard error of mean.

[y] Orthogonal polynomial contrasts : Linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion levels

Table 4. Particle size separation of grains, bunk samples and orts of experimental rations

	% Fraction (DM Basis)		
	Hulls	**Large particles**	**Fines**
Rolled Oat	10.9 ± 3.12	71.7 ± 7.59	17.4 ± 5.63
Rolled Barley	3.4 ± 0.90	67.4 ± 8.40	29.2 ± 8.35
Trt 1	9.3 ± 0.79	70.7 ± 6.01	19.9 ± 5.86
Trt 2	12.1 ± 1.51	65.9 ± 5.18	22.0 ± 4.03
Trt 3	16.2 ± 1.48	61.2 ± 6.96	22.6 ± 7.12
Trt 4	19.0 ± 2.06	65.2 ± 7.03	15.8 ± 6.03
Trt 5	21.1 ± 2.68	65.1 ± 5.82	13.8 ± 4.79
Orts 1	10.3 ± 1.15	72.0 ± 2.32	17.6 ± 1.34
Orts 2	12.3 ± 1.04	72.1 ± 3.35	15.6 ± 3.07
Orts 3	17.2 ± 2.37	66.9 ± 2.67	15.9 ± 3.49
Orts 4	19.8 ± 2.57	69.2 ± 2.51	11.1 ± 0.95
Orts 5	22.6 ± 4.20	66.2 ± 3.95	11.2 ± 1.84

Values: Mean (% basis) ± standard deviation of the mean
Trt 1 to 5: Bunk samples with increasing inclusion levels (0, 25, 50, 75 and 100%) of CDC SO-I
Orts 1 to 5: Feed leftovers with increasing inclusion levels (0, 25, 50, 75 and 100%) of CDC SO-I

Table 5. Effects of different inclusion levels of barley and oat (CDC SO-I) on the carcass characteristics of feedlot steers

	Barley grain : CDC SO-I oat						Contrasts[y]			
Parameter	**100:0**	**75:25**	**50:50**	**25:75**	**0:100**	**SEM[x]**	**Linear**	**Quadratic**	**Cubic**	**Quartic**
Carcass wt (kg)	376	372	368	365.5	362.3	1.93	<0.0001	0.68	0.9	0.82
Dressing %	58.9	58.9	58.4	57.8	58	0.22	0.0007	0.62	0.06	0.87
Average fat (mm)	8.8	8.5	9	7.8	7.3	0.5	0.033	0.25	1.00	0.25
Grader Fat (mm)	7.8	7	7.8	6.5	6	0.46	0.014	0.39	0.61	0.12
Grader REA(cm2)	100.3	97.5	96	98.8	96.8	1.61	0.28	0.35	0.26	0.39
Ruler Yield %	61.8	61.8	61.5	62	62.3	0.3	0.201	0.28	1.00	0.43

[x] Pooled standard error of mean.
[y] Orthogonal polynomial contrasts : Linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion levels

Table 6. Ultrasonographic measurements on back fat thickness and rib eye area of steers fed diets consisting of different levels of barley and CDC SO-I oat

	Barley grain : CDC SO-I oat						Contrasts[y]			
Parameter	**100:0**	**75:25**	**50:50**	**25:75**	**0:100**	**SEM[x]**	**Linear**	**Quadratic**	**Cubic**	**Quartic**
Subcutaneous fat depth(mm)										
Initial	4	4	4.3	4.3	4.3	0.27	0.39	0.81	0.77	0.74
Final	8	8	8.3	7.5	7.5	0.4	0.069	0.205	1	0.47
Longissimus dorsi area (cm^2)										
Initial	78.3	77.5	76.8	76.3	75	1.36	0.11	0.96	0.69	0.59
Final	102.5	101.3	99	99	96.3	1.48	0.0064	0.89	0.71	0.51

[x] Pooled standard error of mean.
[y] Orthogonal polynomial contrasts : Linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion levels

Table 7. Percentage of steers fed diets consisting of different levels of barley and CDC SO-I oat with different marbling scores

Marbling Score	Barley grain : CDC SO-I oat						
	100:0	75:25	50:50	25:75	0:100	SEM[x]	P Value
A	2.5	28.3	17.5	11.1	34.3	6.5	0.07
AA	77.6	66.6	65.0	72.3	62.9	8.1	0.71
AAA	19.9	5.1	17.5	16.7	2.8	5.7	0.27

[x] Pooled standard error of mean.

Study 2: Rumen fermentation characteristics and feeding behavior of cattle fed CDC SO-I oat as compared to barley

Introduction

The manipulation of rumen fermentation is of interest in the case of dairy cows where the ratio between the glycogenic and non-glycogenic volatile fatty acids affects milk composition and also body energy gain (Orskov et al. 1973). In feedlot animals, manipulation of rumen fermentation results in a change in the proportions of propionic, butyric and acetic acids. Methane production decreases with increased propionic acid production, however it increases with increased production of acetic and butyric acid (Orskov et al. 1973). It is also important to mention here that the rate of cereal grain fermentation in the rumen can affect cattle performance and incidence of acidosis. A high extent of fermentation is desired with typical feedlot rations in order to maximize energetic efficiency, but for prevention of acidosis a slow rate of fermentation is preferred (Owens et al. 1998). Availability of highly fermentable starch results in rapid production of fermentation acids which can disrupt the normal rumen environment, increasing the incidence of bloat (Cheng et al. 1998). Bloat and laminitis have adverse effects on the performance of the animal. As compared to corn, barley is highly fermentable in the rumen and thus little starch is available to be digested in the small intestine. Because of this reason, finishing cattle consuming corn based high concentrate diets show improved performance as compared with barley-based diets (Boss and Bowman 1996b). Little information is available on the rumen fermentation characteristics of CDC SO-I oat in comparison to commonly used cereal grains such as barley. Hence, the present study was conducted to investigate the effect of inclusion levels of CDC SO-I oat on the rumen environment (Rumen pH, volatile fatty acids, ammonia and osmolality) including feeding behavior.

Materials and Methods

Animals

Five spayed Hereford heifers (480 ±70 Kg) surgically fitted with soft plastic ruminal cannula of 10 cm diameter opening (Bar Diamond, Parma ID) were used to investigate the effects of CDC SO-I oat on rumen fermentation parameters. The animals were housed

and fed in individual pens in the Livestock Research Building at the Department of Animal and Poultry Science, University of Saskatchewan. Pens were 13 m^2 in size, with steel panel structure outfitted with rubber floor mats and individual automated water bowls. The animals used for this experiment were cared as per the guidelines laid down by Canadian Council on Animal Care (1993).

Experimental Design and Dietary Treatments

The experimental design was a 5 × 5 Latin square. The five treatment diets were the control diet composed of barley grain (80%), barley silage (15%) and pelleted supplement 5% (as fed basis). For the 4 treatment diets barley grain was replaced by CDC SO-I oat at 25, 50, 75 and 100% (as fed basis). Each treatment diet had the same proportion of forage and concentrate (as fed basis) and was formulated as per NRC (1996) recommendations for energy and protein. Each treatment contained 27.4 mg kg^{-1} monensin sodium (DM basis; Elanco Animal Health, Calgary, AB, Canada) (Table 1). The ingredient composition of each supplement is given in Table 1. Each morning fresh feed was weighed and mixed before feeding. Animals were fed twice daily at 0800 and 1600 to maintain a relatively stable rumen environment. Feedbunks were cleaned each morning prior to feeding and orts were weighed to determine the daily feed intake.

The barley grain was grown at the University of Saskatchewan, Goodale Farm. CDC SO-I oat were grown at the University of Saskatchewan farms in Saskatoon and cleaned in Bradwell, SK. Rolling of both the barley and oat was done at the university feedmill with dry rolling using a Roskamp Series 9 Model J double roll roller mill with fine and coarse groove roll sets.

Each trial period was 28 days in duration including adaptation (14 days), intake (7 days) and collection period (7 days). Animals were gradually adapted to the assigned experimental diets from day 1 through day 14. From day 14-21, the voluntary intake of each animal was measured by offering high concentrate experimental diets approximately 10% higher than ad-libitum intake. Day 21 to 28 of each period was used for data collection. The heifers were monitored visually for eating and ruminating behavior for a 24 hour period on day 21. From day 22-24 restricted feed (90% of VI) was offered to all

heifers. Feed restriction was done to ensure complete consumption of diets. Rumen fluid was collected on day 24.

Feeding Behavior

On day 21 of each period, feeding behavior including time spent eating, ruminating, drinking, lying and standing (Yang et al. 2000) was recorded for each animal starting at 0800 h. This behavior was recorded at 5 min intervals over a 24 h period. This protocol was based on previous studies which assumed that the every behavioral activity lasted for five minute. The observation methods were adapted from earlier studies (Yang et al. 2001; Maekawa et al. 2002a, 2002b). Total time spent eating and ruminating were taken together to calculate the total time spent chewing and results were reported as time in minutes.

Rumen Fluid Collection

Samples of rumen contents were collected every 2 h for 24 h on day 24 of each period for ruminal osmolality, volatile fatty acids (VFA), ammonia-nitrogen (NH_3-N), and for recording rumen pH. Samples were collected prior to feeding at 0800 and 1600 h. Ruminal contents were collected via the rumen cannula from 4 different regions (rumen mat, reticulum, dorsal sac, and ventral sac). The collected ruminal contents were combined and then strained through 4 layers of cheesecloth. Rumen pH was measured in duplicate immediately after straining using a portable pH meter Model 265A (Orion Research Inc., Beverly, MA). A 5-ml sub-sample of strained ruminal fluid was mixed with 1 ml of 25% (wt/vol) meta-phosphoric acid (HPO_3) for determination of VFA concentrations. Another 5-ml sub-sample was mixed with 1 ml of 1% (vol/vol) H_2SO_4 for later determination of ammonia nitrogen. A 5-ml sub-sample was collected for determination of osmolality. All samples were stored at -20°C until analyzed.

In-dwelling continuous pH measurements

From day 26 to day 28 of each period, in- dwelling pH measurements were taken using the Indwelling Continuous pH System (Dascor, Escondido, CA) as described earlier (Penner et al. 2006). Briefly, the data logger and pH electrode was weighted with two

weights and placed within the ventral sac of rumen. The attached weights help in maintaining the position within the rumen sac. This system continuously measures pH over a 23 h period at 30 s intervals. Probes were taken out daily from the rumen between 0700 and 0800 h. They were cleaned, standardized (pH 4 and 7) and the recorded data was downloaded daily for further analysis. Rumen pH data obtained from indwelling pH probes over the 23 h period for all three days was averaged for each minute to obtain the minimum pH, mean pH and maximum pH. The pH data collected was divided into three categories: mild (pH 5.8-5.5); moderate (pH 5.5-5.2) and acute (pH <5.2) (Penner et al. 2007). These pH profiles provided basis to determine the state of ruminal acidosis of each animal. Additionally, total time (min/d) and total area (pH*min) for each pH range was calculated.

Chemical Analysis

Each individual feed ingredient and bunk samples of total mixed ration were collected for each period throughout the trial for analysis. Forage samples were oven dried at 55 °C for 48 h to determine the DM content. All samples were then ground using a hammer mill to pass through a 1-mm screen (Christy & Norris Laboratory Mill, Christie- Norris Ltd, Chelmsford, UK). Dry matter content of feed samples was analyzed by drying at 135°C for 2 h (AOAC, 1990; method 930.15). NDF with heat stable α-amylase and sodium sulfite (Van Soest et al., 1991) and ADF content of the feed samples were analyzed with an Ankom 200 fibre analyzer ^{TM} (Ankom Technology, NY) (method 973.18). Acid detergent lignin (ADF method 973.18 followed by 72% H_2SO_4 treatment) and ether extract (method 920.39) were determined (AOAC, 1990). Crude protein was analyzed using 2400 Kjeltec auto-analyzer unit (FOSS Analytical, Hillerød, Denmark). Ca and P were analyzed after ashing for 5 h at 500°C using atomic absorption and UV visible spectrophotometer, respectively. All measurements were performed in duplicate.

Volatile Fatty Acid Analysis

For VFA analysis, acidified rumen fluid samples were first thawed and then centrifuged at 4200 rpm for 15 min at 4 °C using a Beckman Centrifuge (Model J6-MC; Palo Alto, CA). One ml of supernatant was then pipetted into microcentrifuge tubes. To this 450 µL

of solvent (Acetonitrile) and 50 µL of internal standard (97.91 mM Trimethylacetic in methanol) was added and further centrifuged at 13.3×g for 10 min at 4 °C using a microcentrifuge (Model 17 R-MC ; Palo Alto, CA). The supernatant was subsequently transferred into GC vials for analysis. In each sample, acetate, propionate, isobutyrate, butyrate, isovalerate, valerate were analyzed by injecting into an Agilent 6890 Series GC system (Wilmington, DE). Ten µL of samples were injected in an Agilent Technologies high performance GC Capillary Column (30.0 m × 320 µm × 0.25 µm, Wilmington, DE) using an Agilent 7683 Series injector (Wilmington, DE). Injector and flame ionization detector temperature was held constant at 250 °C. A calibration curve was prepared from internal and external standards to calculate the molar proportion of each VFA. Standards used to prepare a standard curve were purchased from Nu-Chek Prep, Inc. (Elysian, MN). Total VFA concentration was calculated by adding the concentrations of all individual acids (Ghorbani et al. 2002; Beauchemin et al. 2003a).

Rumen Ammonia Concentration

The ammonia concentration of rumen fluid was analyzed using phenol-hypochlorite method (Broderick and Kang 1980). Briefly, frozen acidified rumen fluid samples were thawed and centrifuged at 18000 ×g for 10 min at 4°C using a microcentrifuge (Model 17 R-MC ; Palo Alto, CA). Fifty µL of supernatant was then diluted with 2.5 mL of phenol reagent and 2.0 mL of hypochlorite reagent and mixed. The samples were then placed in 95°C water bath for 5 min. After cooling, each sample was analyzed in duplicate along with standards and blanks. The coefficient of determination for calibration curves for these analytes approached 0.98, indicating a high degree of precision and reproducibility. Ammonia concentration was analyzed at 630 nm using a SpectraMax Plus Spectrophotometer (Molecular Devices, CA, USA).

Rumen Fluid Osmolality

Rumen fluid osmolality was analyzed by using a Vapro™ Vapor Pressure Osmometer (Model 5520; Wescor Inc., Logan, Utah). For analyzing osmolality, first the osmometer was calibrated using standards 290, 1000 and 100 mOsm/L. Frozen non- acidified samples were thawed and then centrifuged at 2000 rpm for 15 min using a Beckman

Centrifuge (Model TJ-6; Palo Alto, CA). Analysis of each sample was done in duplicate and if the second reading was not ± 3 mOsm/L of the first reading, further readings were taken until two consecutive readings with ± 3 mOsm/L was obtained.

Statistical Analysis

The Proc Mixed Procedure of the Statistical Analysis System 9.1 (SAS Institute, Inc. 2003) was used to carry out the analysis of variance for all rumen fermentation parameters (pH, VFA, Ammonia and osmolality concentration) and feeding behavior. Proc Mixed Procedure was used for repeated measures with heifer as a random effect and treatment as fixed effect. Statistical significance was assumed to exist when the probability of making a type I error was less than 0.05 and trends were discussed with $P < 0.10$. The Kenward Roger adjustment was used on denominator degrees of freedom. Polynomial orthogonal contrasts were used to test the linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion level on rumen fermentation parameters and feeding behavior.

Results and Discussion

Table 2 shows that there was minimal effect of CDC SO-I inclusion level on rumen pH. Mean rumen pH for the barley-based diet was 5.88. Cattle fed the barley-base diet spent a total of 73, 40 and 14 min below pH cutoff values of 5.8, 5.5 and 5.2, respectively. These cut-off values represent pH values associated with mid, moderate and severe acidosis, respectively. Cattle fed 100 % CDC SO-I oat had a mean pH of 5.5 and tended to spend a longer period of time below each of these critical cut-off points, although there was no statistical effect of oat inclusion level on these parameters (Table 2). Atkinson et al. (2006) also reported that supplementation with safflower oil at (0 to 9% of DM) had no influence on rumen ph. Similarly Zinn (1989) and Elliott et al. (1996) found no effect of a variety of supplemental fat sources at inclusion rates up to 8% of DM on rumen pH. Similar if not numerically lower rumen pH for the oat fed cattle and numerically higher total VFA concentrations indicates that ruminal degradation of the oat starch is similar to that of barley starch. The literature is somewhat conflicting in this area. Herrera-Saldana (1988 & 1990) found in one study that oat starch was degraded at a slower rate than that

of barley while in another study reported oat starch was degraded faster than wheat, barley and corn. The relative low mean daily rumen pH of the oat-fed cattle (5.5) indicates an acidic rumen and that as with feeding barley-based diets, cattle feeders must look at proper feeding management and bunk management procedures to minimize problems with acidosis and other digestive disorders. It is also important to note that oat addition did not decrease total VFA production. Such a result would be expected if a toxic effect of long chain fatty acid release on rumen bacteria was occurring due to the level of oil in the oat and its fatty acid composition.

Little effect of CDC SO-I oat inclusion rate was noted on rumen osmolality, total volatile fatty acid levels or on the molar proportion of individual fatty acids other than minor effects on isovalerate (Table 4). These results mirror those of Elliott et al. (1996) who fed a variety of fat sources to supply 5% fatty acids to the diet of dairy cows. They contrast however with those of Zinn (1989) and Atkinson et al. (2006) who noted that acetate decreased while propionate increased with up to 9% added fat from tallow/blended animal-vegetable fat or safflower oil, respectively.

No effect of treatment was noted on eating behavior other than a greater amount of time spent eating for cattle fed the 50% barley:50% oat treatment.

Conclusion:

The results of this study show that replacing barley with CDC SO-I oat does not change the rumen environment in terms of rumen pH, VFA levels or rumen osmolality. However, it should be noted that as with barley feeding the oat based diets resulted in significant time below critical cut-off values associated with mild to severe acidosis. This indicates that as with barley, cattle feeders must take steps to ensure proper feeding and bunk management protocols that aim to minimize acidosis related concerns and to minimize reduced performance associated with digestive disturbances.

Table 1. Ingredient and chemical composition of treatment diets used for metabolic trial

	Barley grain : CDC SO-I oat				
	100:0	**75:25**	**50:50**	**25:75**	**0:100**
Ingredient Composition (% DM basis)					
Barley Silage	8.23	8.23	8.23	8.23	8.24
Pellets	5.36	5.37	5.37	5.37	5.37
Barley	86.41	64.82	43.22	21.62	0.00
Oats (LLHF)	0.00	21.58	43.18	64.78	86.39
Total	100.00	100.00	100.00	100.00	100.00
Pelleted Supplement (% DM basis)					
Barley	48.88	50.92	51.94	52.96	53.99
Limestone	22.85	22.90	22.93	22.96	22.99
Rum Premix [1]	7.19	7.21	7.21	7.22	7.23
Urea	5.39	3.24	2.16	1.08	0.00
TM salt[2]	7.07	7.09	7.10	7.11	7.11
LS106[3]	8.63	8.65	8.66	8.67	8.68
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition (% DM basis)					
DM %	85.1	83.8	84.7	84.6	85.9
CP %	11.6	12.8	12.9	12.9	13.5
NDF%	23.9	25.3	26.2	27.9	29.2
ADF%	9.1	10.0	10.3	11.6	12.4
ADL%	3.1	2.8	2.7	2.3	1.9
Ether Extract	2.6	3.5	4.4	5.6	6.7
Calcium %	0.61	0.64	0.66	0.66	0.68
Phosphorus %	0.41	0.43	0.40	0.40	0.39

1. Contained Barley 97%, Rumensin premix (Monensin Sodium 1000 mg/kg) 3%
2. Contained Zinc 10,000 mg/kg, Iodine 200mg/kg, Manganese 10,000 mg/kg, Copper 4000 mg/kg, Cobalt 60 mg/kg, Selenium 120 mg/kg, Salt 95%
3. Vitamin A 440500 IU/kg, Vitamin D 88,000 IU/kg

Table 2. Measurements of rumen pH of heifers fed increasing inclusion levels of CDC SO-I oat.

	Barley grain : CDC SO-I oat Ratio %						P-Value Contrasts[y]		
	100:0	75:25	50:50	25:75	100:0	SEM[x]	Linear	Quadratic	Cubic
Mean Daily Rumen pH									
In-Dwelling pH	5.88	6.07	5.89	5.95	5.53	0.156	0.97	0.55	0.21
Spot Sample pH	6.14	6.11	6.06	6.05	6.02	0.120	0.26	0.87	0.99
Rumen pH Parameter 5.8 or lower									
Mean pH	5.45	5.48	5.45	5.45	5.28	0.076	0.79	0.75	0.70
Total time (min)	127.5	134.9	117.9	165.0	373.4	98.29	0.81	0.82	0.82
Time between 5.8 & 5.5 (min)	73.0	95.1	65.0	110.0	189.8	64.77	0.76	0.84	0.62
Rumen pH Parameter 5.5 or lower									
Mean pH	5.18	5.35	5.32	5.32	5.18	0.077	0.30	0.28	0.48
Time between 5.5 & 5.2(min)	40.4	30.3	29.9	37.5	113.2	24.55	0.93	0.71	0.99
Rumen pH Parameter 5.2 or lower									
Mean pH	4.94	5.08	5.04	5.09	4.86	0.128	0.36	0.66	0.57
Time below 5.2(min)	14.1	9.5	24.1	17.5	70.4	16.04	0.69	0.94	0.53

[x] Pooled standard error of mean.
[y]Orthogonal polynomial contrasts : Linear, quadratic and cubic effects of CDC SO-I oat inclusion levels

Table 3. Effects of increasing inclusion levels of CDC SO-I oat on rumen fluid parameters of heifers.

	Barley grain : CDC SO-I oat							P-Value Contrasts[y]			
	100:0	75:25	50:50	25:75	0:100	SEM[x]	P_{Time}	Linear	Quadratic	Cubic	Quartic
Total VFA(mM/L)	93.6	97.3	93.3	98.9	101.5	5.94	<0.0001	0.29	0.70	0.78	0.49
Acetate %	51. 6	53.0	54.3	49.7	50.9	3.06	<0.0001	0.63	0.57	0.53	0.49
Propionate%	31.9	34.9	31.5	37.6	35.9	4.17	<0.0001	0.31	1.00	0.88	0.24
A:P ratio	1.8	1.8	2.2	1.4	1.5	0.42	<0.0001	0.44	0.60	0.68	0.26
Isobutyrate %	0.9	0.8	0.8	0.6	0.6	0.14	0.0003	0.05	0.78	0.78	0.71
Butyrate %	11.0	7.9	8.7	8.3	8.8	1.68	0.0002	0.46	0.34	0.58	0.61
Isovalerate %	2.6	1.5	2.4	1.6	1.9	0.74	<0.0001	0.50	0.63	0.58	0.20
Valertae %	1.7	1.6	1.8	1.9	1.6	0.43	0.80	0.90	0.82	0.65	0.93
Osmolality (mOsm/L)	283.3	277.1	270.5	288.6	288.5	12.37	<0.0001	0.55	0.40	0.62	0.48

[x] Pooled standard error of mean.

[y] Orthogonal polynomial contrasts : Linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion levels

Table 4. Effects of increasing inclusion levels of CDC SO-I oat on dry matter intake and feeding behavior of heifers fed high concentrate diets.

	Barley grain : CDC SO-I oat						P-Value Contrasts[y]			
	100:0	75:25	50:50	25:75	0:100	SEM[x]	Linear	Quadratic	Cubic	Quartic
DMI (Kg)	11.36	11.54	11.4	10.94	10.52	0.63	0.10	0.34	0.78	0.92
Time (min/day)										
Eating	68	84	132	89	108	8.30	0.001	0.003	0.150	0.0002
Ruminating	314	288	327	269	292	23.58	0.41	0.99	0.83	0.10
Chewing[z]	382	372	459	358	400	26.69	0.80	0.41	0.59	0.014
Drinking	21	31	16	37	21	3.60	0.61	0.25	0.31	0.0004
Lying	243	237	227	231	216	23.35	0.45	0.98	0.82	0.80
Other	859	822	804	842	803	36.38	0.44	0.72	0.40	0.59

[x] Pooled standard error of mean.
[y] Orthogonal polynomial contrasts : Linear, quadratic, cubic and quartic effects of CDC SO-I oat inclusion levels
[z] Chewing = Eating + Ruminating

Study 3: Effect of Processing of Low Lignin Hull, High Oil Oat on the Performance of Backgrounding calves.

Introduction:

Recently, the Crop Development Center at the University of Saskatchewan developed a new variety of oat CDC SO-I, with low lignin hull and high oil groat. This new variety of oat available to growers in 2009and is specially developed for the ruminant feed market. Previous feeding trials with initial lines of this variety have shown promise in both dairy and beef feeding trials, particularly in backgrounding programs. Zalinko and McKinnon (unpublished) fed 124 crossbred calves (steers and heifers sorted by sex and weight) one of two diets consisting of whole or dry-rolled low lignin hull, high oil groat oat (LLH-HOG) to determine the effect of processing on performance of backgrounding calves. There was no difference in average daily between cattle fed the whole vs. the rolled LLH-HOG oat (0.94 vs. 0.97 kg/d). Gain to feed ratios were 0.125 vs. .135 for the whole vs. the rolled oat fed cattle. Dry matter intakes were not significantly different between the 2 treatments. The results indicated that at levels used in this trial, the LLH-HOG oat when fed whole are as digestible as when fed dry rolled. Presumably, the low-lignin nature of the hull is responsible for this observation. This observation is an extremely important finding for the cattle backgrounding industry. Processing cereal grains either by rolling or grinding is a significant cost. Estimates range from $5 to $15 per tonne, based on method and size of operation. If the LLH-HOG oat can be fed whole to growing cattle with no loss in performance, significant economic benefits can be achieved. Further research on this oat variety is necessary to answer the question – "***Is processing required for optimal utilization of this feed grain"?***

The objective of this study was to compare the performance of backgrounding cattle fed hay-based backgrounding diets using dry rolled barley; dry rolled or whole SO-I oat as a grain source.

Materials & Methods

One hundred and five commercial cross-bred calves weighing 273 ± 14 kgs (mean ± SD) were assigned to one of 15 pens (7 head/pen) at the WBDC Termendue Ranch at Lanigan, Sk. The calves were supplied by Pound-Maker Ag-ventures of Lanigan, Sk. The cattle had been processed prior to arrival according to the receiving protocol of Pound-Maker Agventures Ltd. Diets were comprised of alfalfa-brome hay (63%), mineral supplement (2%) and grain source (dry-rolled barley, dry rolled SO-I or whole SO-I at 35%). Table 1 gives the ingredient make up and chemical composition of the experimental diets. Crude protein and mineral requirements were formulated for 1.2 kg /day weight gain as per NRC (19996). The trial was designed to last for 105 days with a target end of test weight of 400 kgs.

Results and Discussion:

Chemical analysis of the complete diets shows that crude protein levels ranged from 11. 3 % for the barley based diet to 11.6% for the 2 oat based diets (Table 1). These levels met NRC (1996) requirements for the type of cattle used and rate of gain observed in this study. ADF and NDF levels were lower for the barley diet relative to the 2 oat-based diets, an observation consistent with the higher fibre levels of oat relative to barley grain (Table 1).

Table 2 gives the performance information of the calves fed the 3 diets. There were no significant differences in average daily gain between cattle fed the 3 diets (Figure 1). However, feed intake was highest for cattle fed the rolled oat and lowest for those fed the whole oat diet with the barley grain intermediate (Figure 1). While not significant (P =0.13), cattle fed the whole oat diet had the lowest feed to gain ratio (7.15:1), followed by the rolled oat diet (7.32:1) and the barley diet (7.87:1). There were no differences in ultrasound backfat or longissimus dorsi area at the end of the 105 day period. The minimal amount of subcutaneous fat at the end of this period indicates that the aims of the backgrounding trial were achieved with all diets, that being minimal amount of fat development, yet allowing for skeletal and muscle development.

Conclusion:

Based on the results of this trial it is evident that the new variety of oat – CDC SO-I is an excellent feed oat for backgrounding cattle and does not require processing prior to feeding. Performance of calves fed either whole or rolled CDC SO-I oat was at least equal to that of barley-fed calves and in fact feed to gain ratio tended (P=0.13) to be superior for calves fed the whole oat diet. These results indicate that processing (i.e. dry rolling) is not necessary when CDC SO-I oat is fed at approximately 35% of the diet dry matter in diets designed to target approximately 1.2 kg gain in backgrounding programs. As such, in addition to the agronomic benefits of growing oat for feed, producers will save the processing costs typically required for barley feeding programs yet achieve equal performance. These savings typically range fro $5 to $15 per tone depending on operation size and method of processing employed.

Table 1. Ingredient make-up and chemical composition of backgrounding diets

	Dietary Treatment		
Parameter	Rolled Barley	Whole Oat	Rolled Oat
Ingredient Make-up (% DM)			
Alfalfa-grass hay	63.0	63.0	63.0
Cereal grain	35.0	35.0	35.0
Supplement**	2.0	2.0	2.0
Chemical Composition (% DM)			
CP%	11.3	11.6	11.6
ADF %	24.6	27.7	28.6
NDF%	44.2	48.7	47.3
Ca%	0.5	0.5	0.6
P%	0.3	0.3	0.2

** Commercial Mineral Supplement

Table 2. Performance of cross-bred calves fed backgrounding diets based on rolled barley or rolled or whole CDC SO-I oat.

	Dietary Treatment				
Variable	Rolled Barley	Whole Oats	Rolled Oats	SEM	P-value
SOT wt (kg)	272.7	273.6	272.9	2.54	0.97
EOT wt (kg)	391.1	397.6	397.4	3.66	0.36
ADG (kg)	1.13	1.18	1.19	0.03	0.29
DMI (kg/day)	8.5 ab	8.4 b	8.7 a	0.07	0.04
Feed Conversion	7.87	7.15	7.35	0.24	0.13
Feed Efficiency	0.128	0.140	0.136	0.01	0.24
US SC fat (mm)	1.170	1.008	1.366	0.15	0.27
US *l.dorsi* (cm^2)	11.75	10.72	13.48	1.05	0.21

Means within the same row with different letters are significantly different ($P<0.05$).

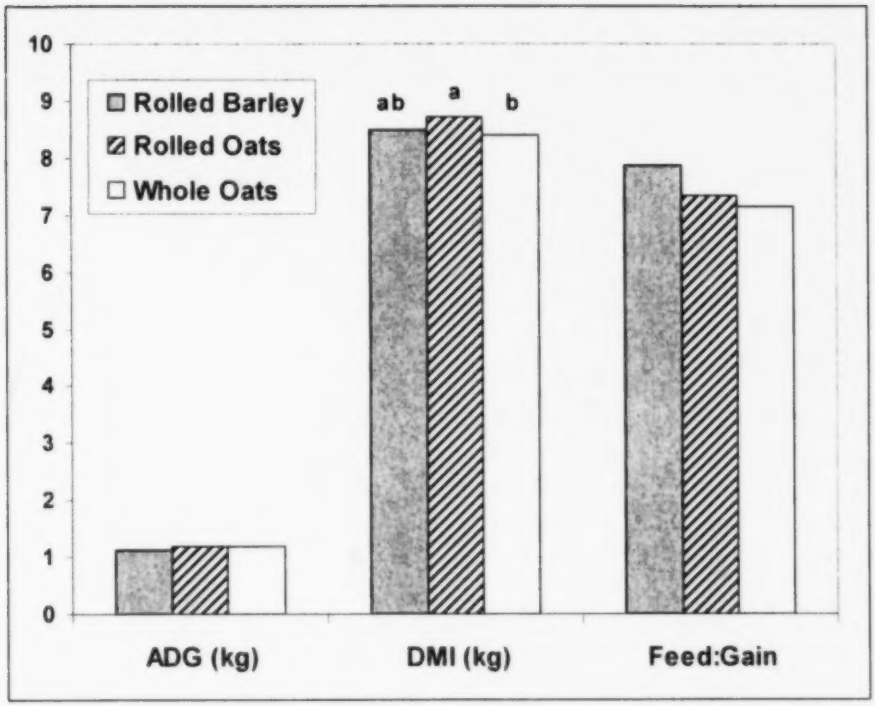

Figure 1. Comparison average daily gain (kg), dry matter intake (kg) and feed conversion of cross-bred calves fed backgrounding diets based on rolled barley or rolled or whole CDC SO-I oat.